

Children's earwitness memory

The influence of age and emotionality

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Abstract

The present study investigated children's abilities as earwitnesses, and examined the influence of age, individual differences, and the emotionality of the auditory stimuli on memory for environmental sound events. Sixty children participated in the study. Twenty-five children aged 7-8 years and 35 children aged 9-11 years were presented two environmental sound events: a car crashing and someone brushing their teeth. The car crash event was postulated to be emotional, and the teeth brushing event neutral. The sound events compiled six individual environmental sounds each, and the participants passively listened to the sound events through a headset. Participants subsequently completed the WASI. After a two week delay, children performed a cued recall, recognition and memory source monitoring task. Children in both age groups recalled and recognized significantly more sounds from the emotional sound event than the neutral sound event. The oldest children recalled significantly more sounds than the youngest children, but no significant age differences were evident in the recognition and source monitoring tasks. In addition, a correlation analysis indicated a significant positive correlation between Full Scale IQ and performance in the cued recall task. Results generally complied with previous literature examining memory in the visual modality, and indicated that children were moderately accurate earwitnesses.

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Introduction

One afternoon, while walking home from playing football with the neighborhood children, a six year old boy named David was suddenly abducted and brought to the garage of a house. The young boy was blindfolded, sexually abused, and left to die in a wooded area near the outskirts of the small town. When the police found David, he was unable to describe how the attacker looked, where he had been, or any other visual detail from the episode because of the blindfold covering his eyes. David was on the other hand very proficient at recalling sounds from the terrible ordeal. During his capture, the young boy had heard a train whistle several times. He also told the police that the man who abused him made a distinct dragging sound when walking, as if he had a limp or an injury. This information lead police officers to the culprit, an adult man previously arrested for child pornography. The middle-aged culprit owned a house next to a railroad crossing, and had a severe limp after a previous injury. DNA evidence corroborated the young boy's story. David's remarkable memory for the auditive stimuli was hence essential in the capture and conviction of his assailant.

As the above anecdote reveals, even young children have the potential to be very accurate witnesses. This has however not always been the general consensus, and the credibility of children's testimonies has been extensively debated (Bartol & Bartol, 2012; Ceci & Bruck, 1995). The historical disbelief in children's memory abilities warrants widespread research into this socially important topic in order to further strengthen the legal protection of children. As the weak party in legal disputes, children are often unable to fully protect themselves, needing the help of professionals that can inform the legal branch about the accuracy of their statements. Increased knowledge will hopefully help protect the rights of child victims and ensure justice for this vulnerable group. Witness psychologists have played a crucial role in increasing the knowledge concerning the testimonies of children, and consequently strengthening the awareness of legal officials.

Earwitness testimony and the memory of environmental sounds hold great legal importance, as the story of little David's abuse indicates. To this date, limited research has investigated earwitness testimonies (Magnussen, 2007; Yarmey, Yarmey, & Todd, 2008). Although some findings from the study of eyewitnesses can be transferred to earwitness testimonies, several factors are probably specific for earwitness testimony and the memory of auditive material. The majority of research regarding earwitnesses has focused on person

identification based on vocal information (Hollien, 1990). Memory for environmental sounds and sound events has on the other hand been minimally investigated (Marcell, Malatanos, Leahy, & Comeaux, 2007). Children's earwitness testimonies are of great importance, and the study of these topics is crucial to insure justice for child victims and witnesses.

Auditive Processing and Sound Stimuli

Sounds are molecular vibrations in air or other media that stimulate the auditory system. The process of hearing starts in the ear, where the vibrations are converted into action potentials in axons of the auditory nerve (Purves et al., 2008). Action potentials then travel up the afferent pathway in the brain stem on route to the brain (Näätänen & Winkler, 1999). This afferent primary auditory pathway reaches the thalamus, where the neuronal signal is further relayed to the primary auditory cortex. The primary auditory cortex is located in the temporal lobe (Pinel, 2000). When arriving at the primary auditory cortex, the incoming auditive stimulus reaches awareness and can be consciously perceived (Näätänen & Winkler, 1999). First order processing of the characteristics of the auditory stimuli occurs in the primary auditory cortex. The secondary auditory cortex surrounds the primary auditory cortex, and is responsible for higher order processing. Pure tones only activate the primary auditory cortex, while more complex sounds such as wideband noise, speech and environmental sounds also activate the secondary auditory cortex (Wessinger et al., 2001). In contrast to speech processing, processing of environmental sounds occur equally in both hemispheres (Purves et al., 2008).

According to Gygi & Shafiro (2007), environmental sounds are naturally occurring non-speech, non-musical sounds. Some examples of environmental sounds are a ball bouncing, a glass braking or a barking dog. Clearly, environmental sounds encompass a broad range of semantic and acoustic complexity (Gygi & Shafiro, 2007). Environmental sounds are often highly familiar (Marcell et al., 2007), resulting from years of experience as well as the acoustic system's natural ability to perceive the sound environment. A large number of environmental sounds can consequently be identified at durations as brief as 500 ms. Since environmental sounds are produced by naturally occurring physical sources, the sounds are a source of information about the listener's surroundings. In addition, environmental sounds are capable of eliciting emotional reactions in the listener, and can affect the listener's mood, productivity and overall satisfaction. The auditive stimuli can emotionally affect the listener

beyond the extent based merely on physical characteristics such as frequency, intensity and duration (Gygi & Shafiro, 2007). Environmental sounds can accordingly elicit emotional reactions comparable to the emotionality elicited by pictures (Bradley & Lang, 2000).

In authentic sound environments, the acoustic stimuli encompass several intermixed sounds (Gygi & Shafiro, 2007). Such auditory scenes are called environmental sound events, and are defined as sequences of closely grouped and temporally related environmental sounds that tell a story or establish a sense of place (McAdams & Bigand, 1993). Environmental sound events are for example the sounds of cooking dinner or a school yard at recess. Previous research has indicated that listeners perceive environmental sound events as familiar events or situations, that the course of events is understandable and that emotional sound events elicit emotional reactions (Marcell et al., 2007). Note however that the identification, familiarity, emotionality and memorability of an environmental sound event is dependent upon context, previous experiences, ecological frequency and personal relevance (Gygi & Shafiro, 2007).

Memory Abilities across Modalities

Studies exploring memory abilities generally report that accuracy of memory performance differs between modalities (Lawrence, Cobb, & Beard, 1979). Memory for pictures has been reported to be extraordinary accurate and robust (Cohen, Horowitz, & Wolfe, 2009; Harand et al., 2012). Across several studies, the mean accuracy was calculated to be an impressive 94 % (Lawrence & Banks, 1973). Memory for auditive stimuli has repeatedly been reported to be well below memory for pictures (Cohen et al., 2009; Snyder & Gregg, 2011). When asked to distinguish between pairs of pictures where one had been previously presented, participants were very accurate in identifying the previously presented pictures compared to the same task performed with environmental sounds (Cohen et al., 2009). Moreover, tactile recognition has also been reported to be superior to auditory memory for environmental sounds (Lawrence et al., 1979). Olfactory recognition has on the other hand been found to be inferior to both acoustic and visual recognition (Zucco, 2003).

The superior memorability of pictures compared to sounds can potentially be caused by greater experience attentively viewing complex visual scenes, resulting in more finely tuned neural resources available for encoding, storing and retrieving visual stimuli compared

to auditory stimuli (Snyder & Gregg, 2011). In addition to modality differences in memory, Cohen and colleagues (2009) and Miller and Tanis (1971) reported differing memory performance within the auditory modality: spoken language was remembered more accurately than environmental sounds. Knowledge of these modality differences is crucial from a legal perspective when evaluating the quality of witness testimonies.

Notably, visual stimuli are generally static pictures, while auditory stimuli are dynamic sounds with continuous spectro-temporal changes. Auditory stimuli take longer time to encode than pictures because the stimulus is spread over time. The reported difference between the memorability of auditory and visual stimuli might be somewhat caused by the difference in memorability between static and dynamic stimuli (Snyder & Gregg, 2011).

The Memorability of Environmental Sounds

When studying the memorability of environmental sounds in psychological experiments, participants are initially presented several environmental sounds or sound events. Encoding of the sounds can be intentional or incidental depending on the amount of information participants are given about the purpose of the study and the subsequent memory test. Following a delay, participants are generally asked to perform a recall or recognition task. During a recall task, participants report every sound they can recall from encoding. When performing a recognition task, participants listen to numerous sounds and report which items were presented during encoding (Clark, Stamm, Sussman, & Weitz, 1974; Crutcher & Beer, 2011).

Studies utilizing recall tasks report that the amount of recalled items range from 23 % (Crutcher & Beer, 2011) to 95 % (Paivio, Philipchalk, & Rowe, 1975) of all presented environmental sounds. Percentage of recalled items depends on the duration of delay, the number of stimuli, the individual task, and whether the encoding was incidental or intentional. Most studies generally report around a 50 % recall among adult participants (Bartlett, 1977; Crutcher & Beer, 2011; Ferrara, Puff, Gioia, & Richards, 1978; Huss & Weaver, 1996; Paivio et al., 1975; Philipchalk & Rowe, 1971; Thompson & Paivio, 1994). Recognition tests have also reported an array of results, ranging from a hit rate of 0.38 (Clark et al., 1974) to 0.89 (Zucco, 2003), again dependent upon several factors. The hit rate for adult participants in most studies is around 0.70 (Clark et al., 1974; Cohen et al., 2009; Cycowicz & Friedman,

1999; Huss & Weaver, 1996; Lawrence et al., 1979; Opitz, Mecklinger, & Friederici, 2000; Röder & Rösler, 2003; Schulze, Vargha-Khadem, & Mishkin, 2012; Zucco, 2003).

Memory accuracy evidently depends on whether encoding was incidental or intentional. Greater memory performance naturally results from intentional encoding compared to incidental encoding (Crutcher & Beer, 2011; Cykowicz & Friedman, 1999; Ferrara et al., 1978; Thompson & Paivio, 1994). Participants who are informed of the subsequent memory test recall significantly more spoken words and sounds than participants who are not aware of the memory test (Cykowicz & Friedman, 1999). In fact, the superiority of intentional encoding is even found when the incidental encoding is semantic and thorough in nature (Ferrara et al., 1978). In a witness psychology perspective, incidental encoding has higher ecological validity and similarity to real life criminal cases, supporting the use of incidental learning in laboratory experiments.

Another important factor influencing the success rate of recall and recognition tasks is the delay between encoding and memory test. Most studies test memory performance the same day as encoding, often only minutes after initial presentation of the stimuli. The limited number of studies utilizing a longer delay report declining memory performance with increased duration (Huss & Weaver, 1996; Lawrence et al., 1979). Long delays are detrimental to memory performance, and this problem may be greater for young children than for older children and adults (Goodman & Melinder, 2007). In fact, longer delay may cause less accurate recall than immediately suggestive questioning (Quas et al., 2007). During legal litigations in Norway, the delay between a criminal incident and questioning of witnesses is on average several weeks (*Et ansvarlig politi: Åpenhet, kontroll og læring* 2009). If preferring to perform an externally valid and generalizable study, a delay of several weeks should be utilized. There is a divergence between this preference for a long delay, and the present state of the duration utilized in the research area. The longest delays that have been used in current published studies of the retention of environmental sounds are only seven days (Huss & Weaver, 1996; Lawrence et al., 1979).

Several other gaps in the current literature are also evident. Only a single study by Marcell and colleagues (2007) report the use of environmental sound events as opposed to individual and incoherent environmental sounds. Understanding of the perception and retention of several environmental sounds making up a coherent and logical sound event is crucial for evaluating the quality of earwitness testimonies. The use of environmental sound

events as opposed to individual environmental sounds has higher ecological validity and ability to generalize to criminal incidents. It is pertinent to assume that memories for individual and incoherent environmental sounds are different than memories for coherent, cohesive and informative environmental sound events.

With the exception of limited literature (Ling & Coombe, 2005), another significant gap in the research literature is the evident lack of child participants. Ling and Coombe (2005) reported that children remembered less of an overheard conversation than adults. However, researchers have yet to clarify the relationship between age and earwitness performance. Children's testimonies are of great interest because of the historical disbelief in their abilities (Bartol & Bartol, 2012). Further studies are needed to efficiently inform the legal branch about the reliability of earwitness testimonies in general, and children's earwitness testimonies in particular.

Development of Episodic Memory

When asking an earwitness to recall or recognize previously encountered auditive material, researchers are interested in memory processes classified as episodic memory. Episodic memory is a form of long-term memory defined as the memory of autobiographical events. Processes of episodic memory are concerned with individual personal episodes, the temporal-spatial relations among these episodes, and the autobiographical importance of these events for an individual's identity (Tulving, 1972). Episodic memory can be contrasted with semantic memory, a memory system responsible for storing factual information about the world. Semantic memory lack the autobiographical narrative evident in episodic memory (Tulving, 1972), such as witness testimonies of criminal events. The medial temporal lobes are mainly responsible for episodic memory, and areas in the frontal lobe and parietal regions are also involved (Purves et al., 2008).

Knowledge about cognitive development in children is crucial when studying children's earwitness testimonies and informing relevant officials of the quality of these testimonies. A multitude of studies have reported increased long-term memory abilities with increased age in children (Eysenck, 2009b; Fivush, 2002). These results have been confirmed both in and outside of the laboratory setting (Gathercole, 1998; Hanten et al., 2007; Howe, 2006). When studying interviews for medical emergencies, younger children performed

poorer than older children (Peterson & Whalen, 2001). Similar results have been reported when interviewing alleged sex abuse victims (Lamb, Sternberg, & Esplin, 2000). There are several differences between memory abilities of young compared to older children (Bruck, Ceci, & Hembrooke, 1998). In general, younger children report less information and fewer details than older children (Hanten et al., 2007; Howe, 2006; Lamb et al., 2000). Additionally, older children recount more accurate narratives of previous experiences (Peterson & Whalen, 2001), and forgetting proceeds more rapidly in younger compared to older children (Lamb et al., 2000). When asked to recall a previous experience, older children's testimony is more complete and consists of the core components: who, when, where and what (Qin, Quas, Redlich, & Goodman, 2002; Reese, 2009).

During encoding of auditive stimuli, the secondary auditory cortex is responsible for higher order processing such as understanding, comprehension, and recognition of sounds. The meaning of the sounds is elaborated and compared to stored knowledge and prior experiences (Purves et al., 2008). Younger children have fewer relevant prior experiences and less stored knowledge for the stimuli to be compared to than older children. Older children are hence more successful at comparing incoming auditive information to stored knowledge. Increased content knowledge helps improve memory abilities because new information is easier to remember when it can be related to relevant knowledge already stored in memory. Older children remember more information than younger children because they have more relevant information to compare and connect the new information to (Eysenck, 2009b; Siegler, 1991). Experience and enhanced knowledge, as well as specific training directly change the auditory cortex. The connectivity in the auditory cortex is somewhat malleable and changeable, presumably to allow experience and knowledge to improve perceptual and behavioral responses (Clapp, Kirk, Hamm, Shepherd, & Teyler, 2005; Kraus & Banai, 2007). While children acquire knowledge as they age and develop, their database of available connections to compare incoming sounds to increases, presumably as a result of changes in connectivity in the auditory cortex (Purves et al., 2008).

Other interacting factors causing memory development in children have also been identified (Siegler, 1991). A range of empirical studies support the importance of these factors. Together, enhancements of the basic capacities of working memory, increased use of memory strategies, and improvement in metamemory all contribute to the development of memory abilities. Basic working memory capacities increase with age in children (Gathercole, 1998; Siegler, 1991) and this memory system is important to the performance of a range of

tasks (Eysenck, 2009b). In childhood years, there is large development of the prefrontal cortex, an area crucial for memory strategies. As a result, children begin to use more sophisticated and effective memory strategies, such as verbal rehearsal (Gathercole, 1998). Additionally, metamemory improve with age, further enhancing memory abilities. Metamemory is knowledge about our own memory, making us capable of for example selecting appropriate learning strategies. Increased content knowledge, working memory, memory strategies, and metamemory probably all contribute to improved memory abilities with increased age in children (Siegler, 1991).

As previously stated, researchers have yet to clarify the relationship between age and earwitness performance. A study by Ling and Coombe (2005) sought to investigate this relationship. 196 participants listened to a relatively long conversation about a previously unknown topic. Approximately half the participants were children between 11 and 16 years and the other half were adults between 20 and 63 years. After one week, participants answered a questionnaire concerning the content of the overheard conversation. Overall, performance was generally quite low. Children performed poorer than adults, and there were no differences in performance between the different ages of children (Ling & Coombe, 2005). These quick conclusions can be misleading. Poorer performance of children compared to adults can potentially be the result of the questioning method. The use of questionnaires is professedly more familiar to adults than children. Furthermore, the lack of age differences in memory performance between the groups of children can be expected because the children were relatively old. Further investigations into the relationship between age and earwitness performance is justified.

Task dependent memory abilities

When investigating the relationship between memory abilities and age in children, recall tests have traditionally been found to be more sensitive to developmental differences than recognition tests (Howe, 2006). There is a larger discrepancy between different age groups when using recall tests compared to recognition tests (List, 1986). Hudson and Fivush (1991) reported that 5 year old children remembered virtually nothing when asked to recall a previous experience. However, when cues were given, considerable memory appeared (Hudson & Fivush, 1991). This discrepancy is probably because children's memories are more dependent on cues than adult's memories (Parkin, 2002). Older children need fewer

cues and probing during recall than younger children (Qin et al., 2002; Reese, 2009), resulting in greater age differences on recall tests than recognition tests.

In addition to reporting what happened and who was there, witness testimonies in criminal cases are reliant on an account of how things occurred. A recent experiment by Melinder and colleagues (2010) investigated the variability of 4 year old children's ability to report different aspects of a medical examination. After a long delay of eight weeks, children had significantly more difficulty in reporting how the medical examination occurred, compared to questions about what happened and who was there. When asked how the examination was done, 81.5% of children responded "I don't know/remember." On the other hand, when the children were asked who was there and what happened, they only responded "I don't know/remember" to 46% and 41%, respectively (Melinder et al., 2010). In compliance with these results, the ability to chronologically order a narrative of an autobiographical event develops during middle childhood (Reese, 2009). Evidently, children can have problems recalling the course of events and how incidents progressed. When asked to recall how an event occurred, larger differences between age-groups are expected compared to questions concerning what happened and who was there. This apparent difficulty in recalling how an event occurred can potentially have profound consequences in criminal trials. Children's testimony can lack the important narrative texture crucial for other people's understanding of a situation.

Individual differences

Memory abilities often differ greatly between children in the same age group. Under the same circumstances and conditions, children of the same age show vast differences in abilities. Apparently, underlying individual differences play a large role in determining children's performance on memory tasks. Intelligence has especially been implicated as an important factor contributing to this individual variance. Greater intelligence is associated with better memory performance (Fivush, 2002; Melinder et al., 2010; Qin et al., 2002), and suggestibility decreases as a function of intelligence (Ceci & Bruck, 1993). Children's abilities to both produce and comprehend language is especially important for memory performance on several tasks, particularly if memory is probed by the use of an interview or a recall task (Qin et al., 2002). Concordantly, studies have revealed that higher verbal intelligence predicts memory accuracy, especially in verbal interviews taxing language

abilities (Melinder et al., 2010). Studies have also failed to report a relation between intelligence, vocabulary abilities and memory accuracy in children (Greenhoot, Ornstein, Gordon, & Baker-Ward, 1999; Gross & Hayne, 1999).

Memory source monitoring

In addition to the obvious importance of remembering the content of a memory of past events, remembering the source and context of the memory is equally central in witness testimonies. Merely remembering that something happened, without recalling when the event occurred, who performed the acts or simply if the memory is fact or fantasy is not adequate when testifying in criminal cases. The origin, or source, of memories refers to several characteristics that, combined, specify the conditions under which a memory was acquired. These characteristics can be the spatial, temporal, and social context of the event, the media and modalities through which it was perceived, or if the memory is real or merely a result of imagination or dream (Johnson, Hashtroudi, & Lindsay, 1993). A failure to monitor memory source can lead to false memories or memory distortions (Ceci, Loftus, Leichtman, & Bruck, 1994), as well as a generally uncertain and vague memory lacking autobiographical character.

There are several types of memory source discrimination. External source monitoring refers to discriminating between externally derived sources. Examples can be discriminating who said what, or which events happened first and second (Johnson et al., 1993). Every memory carries with it certain characteristics stemming from encoding, such as perceptual information, contextual information, semantic detail, affective information, and cognitive operations. Source monitoring decisions employ average differences in these memory characteristics from the various sources. Memories of real events will for example include more perceptual information compared to memories of dreams, while memories of dreams on the other hand will contain more cognitive operations (Johnson et al., 1993). For the most part, these discrimination processes occur spontaneously, quickly and without conscious awareness. Under some circumstances, source monitoring will be more deliberate, effortful and conscious (Johnson et al., 1993).

The developmental trajectory of memory source monitoring has been reported to differ with the type of source monitoring investigated (Lindsay, Johnson, & Kwon, 1991). Even though most memory source monitoring tasks report that children perform poorer than adults

and that older children outperform younger children, some studies have also indicated no differences in performance with varying age (Ceci et al., 1994; Foley & Johnson, 1985; Foley, Johnson, & Raye, 1983; Foley, Santini, & Sopasakis, 1989). Lindsay, Johnson & Kwon (1991) reported that 6 year old children outperformed 4 year olds when asked to discern which information pertained to which of two different videos. Similar age differences in external source monitoring were found by Melinder, Endestad and Magnussen (2006) and Ruffman, Rustin, Garnham, & Parkin (2001). Azkil and Zaragoza (1995) on the other hand reported that 9 and 11 year old children did not differ in the amount of misattributions in an external monitoring task.

Children's development of memory source monitoring abilities is clearly complex and multifaceted. The combined body of literature concerning source monitoring indicates that children can perform as well as adults on certain tasks, whilst their performance is inferior on other tasks. Children are more likely than adults to confuse memories from different sources if the sources are very similar. When the sources of memories are alike, children have considerable difficulty in discriminating between memory characteristics stemming from the different origins. However, if the different sources are relatively discriminable, children perform similar to adults (Lindsay et al., 1991).

The Influence of Emotions on Memory

Yet another aspect that needs to be taken into consideration when studying children's eyewitness testimonies is the effect of emotions on memory. In a witness context, the stimuli to be remembered are often highly emotional in nature. The sound environment during a criminal act can potentially be very emotional and can elicit an emotional reaction in the listener. It is therefore potent to investigate how eyewitness testimonies of neutral material compare to the memory of emotional stimuli. Numerous studies have yielded robust results indicating that emotional memories are more detailed and more resilient to forgetting than neutral memories (Bradley & Lang, 2000; Mirandola, Toffalini, Grassano, Cornoldi, & Melinder, in press; Putman, van Honk, Kessels, Mulder, & Koppeschaar, 2004). This is especially true for central aspects of an event, compared to more peripheral information (Baugerud & Melinder, 2012; Christianson, 1992). When asked to either recall or recognize previously presented pictures, arousing pictures are remembered better than neutral pictures after both short delays (Bradley, Greenwald, Petry, & Lang, 1992; Kensinger & Schacter,

2006) and long delays of up to one year (Bradley et al., 1992; Bywaters, Andrade, & Turpin, 2004). The advantage of arousing material has also been found when participants were asked to recognize previously presented words (Bayer, Sommer, & Schacht, 2011). Interestingly, in a study by Bradley and Lang (2000), the memory advantage of emotional stimuli was also reported for auditory material. After listening to 60 environmental sounds, participants performed an incidental recall task following a short delay. Sounds categorized as highly arousing were recalled significantly better than neutral sounds. Furthermore, the physiological reactivity elicited by listening to arousing sounds was very similar to the pattern of physiological reactions produced when participants were presented emotional pictures (Bradley & Lang, 2000).

Emotionally arousing material can both have a positive and negative valence. Memory tests comparing positive and negative material seldom report a differing memory performance (Bayer et al., 2011; Bradley et al., 1992; Bradley & Lang, 2000; Kensinger & Schacter, 2006). Evidently, it is not stimuli valence, but degree of arousal that influences memorability. Some studies have on the other hand reported differing memory performance between positive and negative material. This variability can professedly be explained by varying levels of arousal between the different stimuli. Differing memorability for stimuli with varying valence is probably due to the corresponding difference in arousal between individual stimulus (Bradley et al., 1992). The effect of valence is often cancelled out when degree of arousal is considered. Traumatic events seem to be the most vivid, detailed and clear memories of all, probably because these events elicit the greatest emotional arousal. This superior memorability of traumatic events is also evident in children (Peterson & Whalen, 2001).

Historically, memories of emotional events have been perceived as extraordinarily accurate and long lasting, giving them the name flashbulb memories. Flashbulb memories are postulated to be so clear and vivid that they are perceived as a movie clip playing for our minds eye (Brown & Kulik, 1977). Supposedly, these extraordinary memories are more or less immune to decay over time. Even though emotionally arousing memories have been found to be remembered better and longer than neutral counterparts, the belief that these memories are resistant to forgetting has been shown to be faulty. Despite high confidence in the accuracy of their memories, participants who are asked to recall a highly emotional public event after a delay of several years tend to be surprisingly inaccurate (Schmolck, Buffalo, & Squire, 2000). Evidently, emotional memories are detailed and long-lasting but nevertheless subject to distortion and decay over time.

The relationship between emotional activation and memory is evidently complex, and arousal impacts several aspects of memory. Emotions professedly influence encoding and consolidation of memories (Hamann, 2001). Emotions influence memory through increased attention during encoding of emotional material compared to neutral stimuli. Increased attention and narrowing of attention around the central emotional details leads to enhanced memory for these details. Increased attention during encoding naturally leads to superior memorability (Phelps, 2006). This is true for both positive and negative stimuli (Kensinger & Schacter, 2006). Emotional arousal is moreover proposed to enhance memory consolidation following encoding, further improving storage of emotional memories (Kleinsmith & Kaplan, 1963). Compared to neutral memories, emotional memories are additionally consolidated following encoding, resulting in strengthened memories for emotional material over time (Phelps, 2006).

In addition to processes operating during encoding and consolidation, emotional memories are postulated to have a higher likelihood of being repeated and rehearsed compared to neutral memories. Increased repetition following encoding leads to improved memorability of the emotional material compared to material lacking in emotional character and importance (Brown & Kulik, 1977). A recent study by Breslin and Safer (2011) reported significant, positive correlations between how much a memory was rehearsed and the accuracy of the memory. Repetition of a memory has also been found to positively correlate with how elaborate and extensive a memory report is (Brown & Kulik, 1977). Rehearsal during storing of a memory can be both overt and covert, and witnesses in criminal cases probably employ both types of repetition between encoding and interview.

The Present Study

Several factors influence the reliability of children's earwitness testimonies. The aim of the present study was to elucidate the role of emotionality, age and individual differences on the recall, recognition and source monitoring abilities of children in an earwitness context. Children aged 7-8 years and 9-11 years were presented two environmental sound events, one emotional and one neutral. They then performed the WASI intelligence test. After a two-week delay, participants were asked to recall all they could remember. A recognition task followed, where the children discriminated between novel (new) and previously presented (old) sounds. Lastly, children were asked to identify the sources of the sounds they reported as old.

Based on previous research, three main hypotheses were proposed. The first hypothesis stated that the emotional sound event would be remembered better than the neutral sound event. This will occur on both the recall and recognition task. The superiority of emotional material over neutral material will not be evident on the memory source monitoring task. Numerous studies have indicated a memory advantage of arousing material over neutral material (Bradley et al., 1992; Bywaters et al., 2004; Kensinger & Schacter, 2006). Limited research has however affirmed this superiority for auditory stimuli (Bradley & Lang, 2000). Knowledge of a potential effect of emotionality and arousal on eyewitness testimonies is crucial in a legal context. In the current study, all children were exposed to both an emotional and a neutral sound event, enabling a prospective difference between emotional and neutral material to appear.

Secondly, older children were hypothesized to outperform younger children in the recall, recognition and memory source monitoring tasks. This assumption is based on the numerous studies showing that older children have superior memory abilities compared to younger children (Eysenck, 2009b; Howe, 2006; Lindsay et al., 1991). Greater memory abilities in older compared to younger children will be evident on the recall, recognition, and source monitoring tasks. Previous studies have taught us to expect slight differences in age variability depending on the particular memory task performed. Since young children are more dependent on cues during recall than older children (Qin et al., 2002; Reese, 2009), we expected to find a greater age difference in the recall test than the recognition test. This is in concordance with previous studies indicating that there is a larger discrepancy between different age groups when using recall tests compared to recognition tests (Ceci & Bruck, 1993; List, 1986).

Studies have revealed that intelligence predicts memory accuracy (Fivush, 2002; Melinder et al., 2010). Intelligence is postulated to be partly responsible for individual differences in memory performance (Fivush, 2002; Qin et al., 2002). Following encoding, children performed the complete WASI to investigate the association between memory and individual measures of general learning capabilities (Wechsler, 1989; Wechsler, 1999). The third hypothesis in the current study thus stated that greater memory performance will be associated with greater intelligence.

Method

The present study is a 2 (age; 7-8 vs. 9-11) x 2 (auditive stimuli; emotional vs. neutral) mixed design, with age as the between-subjects variable, and auditive stimuli as the within-subjects variable. Participants were presented two sound events, and performed a cued recall, recognition and memory source monitoring task after a two week delay. Encoding occurred in a medium sized, colourful room formed as a labyrinth named the Eksploratorium. This study was part of a larger project in the Eksploratorium, and the present study will only comprise data concerning the sound events.

Participants

Sixty children participated in the study. Twenty-five children were between the ages of 7 to 8 years ($M = 7.56$, $SD = 0.41$, 9 males) and 35 children were between the ages of 9 to 11 years ($M = 10.68$, $SD = 0.52$, 15 males). Participants were recruited by contacting elementary schools in the Oslo area, who were asked to administer informed consent forms and invitations to participate in the study to grades with the appropriate age span. If parents or guardians wished to consent to their child's participation, they completed the consent form and delivered the form back to the school. The experimenter collected the consent forms, and the families were later contacted by telephone to set a time for participation. After participation, children received a gift card of 100 NOK or a comparable gift.

Ethical Considerations

The study was approved by The Norwegian Data Protection Authority before recruitment of participants began. In the consent form, families were informed of the intention of the study and their possibility to withdraw from participation at any time. Parents and guardians also received further information upon arrival. The children were however not informed that the study was a memory task and that their memory performance would be tested. Given that the study aspires a high degree of generalizability to criminal cases involving children's testimony, incidental encoding as opposed to intentional learning has higher ecological validity. Parents were asked not to extensively discuss the presented material with the children in order to achieve minimal interference in the memory trace. The study was conducted with the children's safety and comfort in focus.

Stimuli and Apparatus

During encoding in the Eksploratorium, participants passively listened to two sound events: a car crashing and someone brushing their teeth. The sound of the car crash professedly evoked an emotional reaction in the listener and was perceived as negative, while the sound of someone brushing their teeth was perceived as neutral and did not elicit an emotional reaction. Both sound events lasted approximately 50 seconds and consisted of six individual sounds meshed together so as to be perceived as a coherent event or situation (see Table 1). There was a 10 seconds pause between the first and second sound event, and the order of presentation of the sound events were randomized across participants. Individual sounds were acquired from an online database (Music Technology Group of Universitat Pompeu Fabra, 2012). Sounds were chosen and individual sounds were compiled into sound events by the experimenter, focusing on realistic sounds and compilations. The enmeshed sound events were presented to the participants by a GoGear Raga MP3 player from Philips and an MDR-ZX100 headset from Sony. The volume was constant for all participants and set at a comfortable level.

Table 1

Sound event specifications: component sounds and duration in seconds

Sound event	Component sounds	Duration (sec)
<i>Car crash</i>	Car starting and driving	21,0
	Car honking twice	3,3
	Car braking twice	4,0
	Car crashing	5,0
	Scream	2,5
	Baby crying	14,2
<i>Brushing teeth</i>	Walking on hard floor	8,3
	Door open and close	6,4
	Running water	11,9
	Brushing teeth	15,2
	Swallowing	2,9
	Spitting twice	5,3

During the recognition test, participants were presented 36 sounds – the 12 target sounds from the sound events and 24 new distracter sounds. The new sounds were chosen from the same online database (Music Technology Group of Universitat Pompeu Fabra, 2012) by the experimenter, and were nonlinguistic, nonmusical environmental sounds (see Table 2). Focus was again on realistic sounds that were easily recognizable and familiar to children. The mean duration of the distracter sounds was 5.3 seconds, and the longest duration was set to 8 seconds. Target sounds exceeding 8 seconds were shortened to this duration in the recognition task. The resulting mean duration of target sounds was 5.7 seconds. All sounds were presented individually. Analogous to target sounds, half the distracter sounds were emotional and the other half neutral. Additionally, approximately the same proportion of monotonous and repetitive sounds compared to individual sharp sounds was presented in distracters as in targets. Items were presented in a random order and at a comfortable volume constant for all participants. Children listened to the sounds from the speakers of a Samsung Q330 laptop computer.

Table 2

Distracter sounds in the recognition task and their duration in seconds

Emotional sounds	Duration (sec)	Neutral sounds	Duration (sec)
Cat wailing	6,0	Ball bouncing	6,0
Breaking glass	2,0	Clock ticking	8,0
Burping	1,0	Opening tin can	2,0
Cheering and applause	8,0	Turning pages	2,0
Fart	1,0	Sawing wood	8,0
Monkey screaming	8,0	Keyboard typing	8,0
Thunder	8,0	Coin falling	2,0
Barking dog	8,0	Galloping horse	8,0
Gargling	4,0	Doorbell ringing	5,0
Coughing	3,0	Printing	8,0
Laughter	5,0	Stapling	4,0
Gun shots	4,0	Playing ping pong	8,0

Procedure

Memory encoding

Participants and their parents were welcomed by an experimenter, and the children's name and age were registered in a data file. Following a short familiarization with the experimenter and the environment, parents were offered a chance to see the Eksploratorium before the child and experimenter entered. Inside the Eksploratorium, the children performed several tasks and were exposed to different stimuli. Participants watched a short movie clip, interacted with a male actor behaving strangely, performed an experiment involving baking powder and water, and identified sounds by pointing to the concomitant picture. Additionally, participants were exposed to olfactory and tactile stimuli, as well as auditive stimuli in the form of the two sound events. In the current study, only the sound events will be discussed. When children listened to the sound events, they were seated in a chair positioned in a corner with colourful walls in different patterns, and listened to the sounds through a headset (see Figure 1).



Figure 1. The setting where participants listened to the sound events during encoding.

Measures of individual difference

After participants were finished in the Eksploratorium, intelligence was tested with WASI (Wechsler Abbreviated Scale of Intelligence). WASI is based on WISC-III (Wechsler Intelligence Scale for Children – Third Edition) and WAIS-III (Wechsler Adult Intelligence Scale – Third Edition), and is valid, reliable, effective and brief (Wechsler, 1989). Children performed the complete WASI, successfully measuring various facets of intelligence (Wechsler, 1999). WASI consists of four subtests: Vocabulary, Block Design, Similarities and Matrix Reasoning. When performing the Vocabulary and Similarities tasks, participants are asked to orally define words and orally explain similarities between notions, respectively. These two subtests compose the Verbal Scale and yield the Verbal IQ. In the Block Design task, participants replicate geometric patterns within a specified time limit, and the Matrix Reasoning task asks participants to complete gridded patterns by indicating the shape that completes the pattern. Together, the Block Design and Matrix Reasoning tasks compose the Performance Scale and yield the Performance IQ. All four subtests compose the Full Scale and yield the Full Scale IQ, successfully measuring several aspects of intelligence (Wechsler, 1999).

Memory testing

After a two week delay ($M = 14.13$ days, range = 10-17), participants returned, meeting another experimenter in another room so as to minimize memory cueing of the previous visit. Children and parents were informed of the procedure and aim of the memory testing. After a short familiarization with the experimenter and the environment, children were interviewed about the previous visit with either a standard interview or a cognitive interview. These interviews will not be discussed in the present study.

Following the interview, participants performed a cued recall task. Children were provided a picture of the setting where they had listened to the sound events during encoding (see Figure 1), and were asked to recall the sounds they had heard in the order they had been presented. One point was given for every correctly recalled sound, and two points were given if the participants remembered the general gist of the sound event. This score is called recall scores and ranged from 0 to 16 points. The children were additionally appointed one point if the sound was recalled in the correct order inward in the sound event. Recall scores including these additional points are called recall in order scores and ranged from 0 to 28 points. Both

recall scores and recall in order scores were equally divided between the emotional and neutral sound events. The task was scored by the experimenter and saved in a data file.

After the cued recall task, participants performed a recognition task. Thirty-six sounds were presented – the 12 target sounds from the sound events and 24 new distracter sounds. For each sound, participants decided if the sound was present in the sound events or if the sound was novel. The task was scored by the experimenter and saved in a data file. Hit rate and false alarm rate was calculated for each participant. Hit rate refers to the rate of correct detections, and false alarm rate is the rate of distracters erroneously signaled as targets. Individual d' [d prime] scores for every child were then calculated from the child's hit and false alarm rate according to the following formula: $d' = z(\text{hit rate}) - z(\text{false alarm rate})$. d' refers to the sensitivity of the participant's response. Sensitivity is a concept within signal-detection theory, and involves a person's ability to detect a target among a range of distracters or noise (Bernstein, Penner, Clarke-Stewart, & Roy, 2006).

Finally, participants performed a memory source monitoring task. Sounds proclaimed by the children as previously presented were presented again, and participants were asked if the sound had been a part of the car crash event or the tooth brushing event. Children gave their answer by pointing to either a picture of a car crash or a picture of a woman brushing her teeth (see Figure 2). The experimenter scored the task in a data file. For every correctly recognized sound (hits) from the recognition task, children could either assign a correct source or an incorrect source. A ratio score of the amount of sounds appointed to the correct source was calculated. This score was called source memory scores. For falsely recognized sounds from the recognition task (false alarms), children either correctly stated that the sound did not belong to any of the sources, or they failed to reject the sound and appointed a false source to the sound. A ratio score of the amount of correctly refuted sounds was calculated.



Figure 2. Pictures of a car crash and a woman brushing her teeth presented to participants during the source memory task.

Results

Preliminary Analyses

Independent-samples t-tests were conducted to compare the scores for males and females. There was no significant difference in recall scores for males and females, $t(58) = .22, p = .82$, two-tailed. There was also no difference between males and females for recall in order scores, $t(58) = .39, p = .70$, two-tailed, d' scores, $t(58) = .75, p = .46$, two-tailed, and source memory scores, $t(58) = .64, p = .52$, two-tailed.

Independent-samples t-tests were also conducted to contrast scores for children interviewed with the cognitive interview (CI) and the standard interview (SI) preceding the memory tasks, in order to investigate whether the two interview techniques influenced subsequent memory performance differently. One child did not receive an interview before testing, and was excluded from this analysis. In total, 35 children received the standard interview, while 24 received the cognitive interview. No significant differences were found between children who had received the CI and SI for either recall, $t(57) = -.10, p = .92$, two-tailed, recall in order, $t(57) = -.16, p = .87$, two-tailed, d' , $t(57) = -1.01, p = .32$, two-tailed, or source memory scores $t(57) = 1.34, p = .19$, two-tailed. Evidently, there were no differences between children interviewed with the standard and cognitive interviews. Even though some studies have reported that children recall an increased amount of correct information when interviewed with the cognitive interview compared to other interview types (Holliday, 2003), the present results are in concordance with previous studies indicating a lacking difference in the amount of auditive information recalled using different interviews (Memon & Yarmey, 1999).

Of the 60 participants, 30 children were presented the emotional sound event first, and 30 children were presented the neutral sound event first. In order to compare the scores for children who were presented the sound events in the different orders, independent-samples t-tests were conducted. There were no significant differences between the different orders of presentation for recall scores, $t(58) = .48, p = .64$, two-tailed, recall in order scores, $t(58) = .49, p = .63$, two-tailed, d' scores, $t(58) = .16, p = .88$, two-tailed, or source memory scores, $t(58) = .57, p = .57$, two-tailed.

Since no differences concerning gender, type of interview or order of presentation were apparent, recall, recall in order, d' and source memory scores were collapsed across these variables. Thus, these variables were not further regarded in the subsequent analyses.

Cued Recall Task

A mixed between-within subjects analysis of variance was conducted to assess the impact of age group and auditory stimuli on recall scores. The analysis revealed a significant main effect of auditory stimuli, $F(1,58) = 14.997, p = .000, \eta^2 = .205$, with both age groups showing higher recall scores for the emotional sound event than the neutral sound event. The main effect comparing the two age groups was also significant, $F(1,58) = 12.401, p = .001, \eta^2 = .176$, indicating that children aged 9-11 years recalled significantly more individual sounds than children aged 7-8 years. There was no significant interaction between age group and auditory stimuli, $F(1,58) = .161, p = .689, \eta^2 = .003$ (see Table 3).

Table 3

Recall, recall in order, d' and source memory scores for the two age groups, divided by auditory stimuli (emotional and neutral sound event)

	7 -8 years		9 - 11 years		Total score across age group	
	Mean	SD	Mean	SD	Mean	SD
<i>Recall emotional event</i>	1.760	1.562	3.371	2.414	2.700	2.235
<i>Recall neutral event</i>	0.600	1.443	1.943	2.300	1.383	2.084
<i>Recall total</i>	2.360	2.378	5.314	3.676		
<i>Recall in order emotional event</i>	2.240	1.921	5.257	3.995	4.000	3.599
<i>Recall in order neutral event</i>	0.920	2.272	2.857	3.423	2.050	3.127
<i>Recall in order total</i>	3.160	3.472	8.114	5.820		
<i>d' emotional event</i>	1.602	0.728	1.941	0.902	1.800	0.844
<i>d' neutral event</i>	1.223	0.740	1.484	1.165	1.375	1.011
<i>d' total</i>	1.351	0.545	1.675	0.906		
<i>Source memory emotional event</i>	0.799	0.268	0.939	0.119	0.881	0.206
<i>Source memory neutral event</i>	0.855	0.242	0.920	0.160	0.893	0.199
<i>Source memory total</i>	0.834	0.193	0.929	0.118		

A mixed between-within subjects analysis of variance was also conducted to assess the impact of age group and auditory stimuli on recall in order scores. A significant main effect of auditory stimuli was evident, $F(1,58) = 13.519, p = .001, \eta^2 = .189$, with both age groups showing higher recall in order scores for the emotional sound event than the neutral sound event. The analysis also revealed a significant main effect of age group, $F(1,58) = 14.408, p = .000, \eta^2 = .199$, indicating that the older children outperformed the younger children. There was however no significant interaction between age group and auditory stimuli, $F(1,58) = 1.139, p = .290, \eta^2 = .019$ (see Table 3).

Recognition Task

In order to illustrate the sensitivity of participants in the recognition task, a ROC curve was created. When plotting hit rate against false alarm rate for every individual participant, a diagonal line reflects chance outcomes, and the data points in the top left corner has the highest d' scores. The individual data points fall above the diagonal line if the participants performed above chance. As figure 3 depicts, all participants performed above chance, with smaller variations.

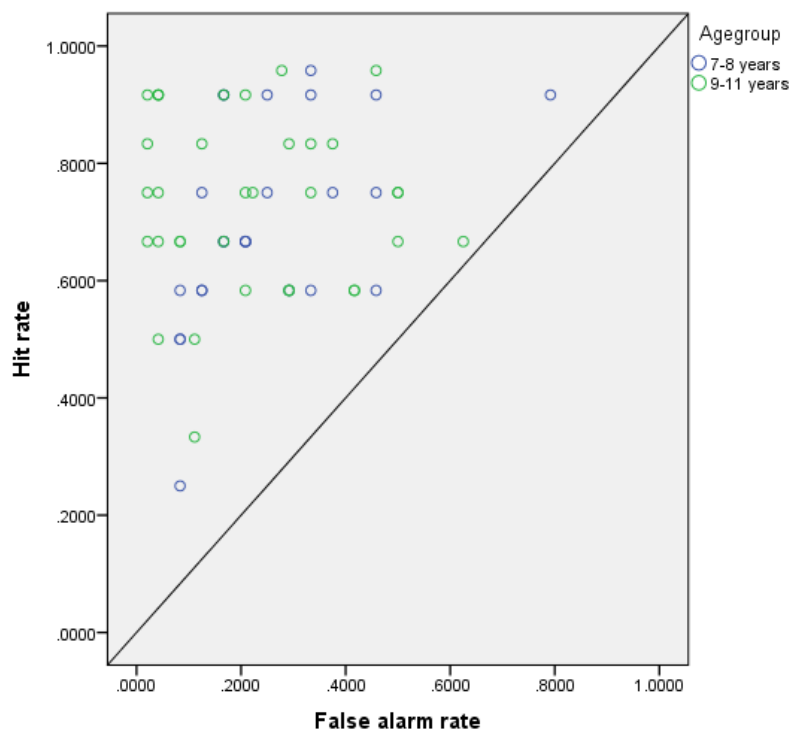


Figure 3. A ROC curve plotting false alarm rate against hit rate for every participant, divided by age group

A mixed between-within subjects ANOVA was conducted in order to discern the effects of age group and auditory stimuli on d' . The analysis revealed a significant main effect of auditory stimuli, $F(1,58) = 9.103, p = .004, \eta^2 = .136$, with both age groups showing a higher d' for emotional sounds than neutral sounds. There was on the other hand no significant main effect of age group, $F(1,58) = 2.267, p = .138, \eta^2 = .038$, and no significant interaction between age group and auditory stimuli, $F(1, 58) = .079, p = .779, \eta^2 = .001$ (see Table 3). Figure 3 effectively illustrates the lacking significant difference between the two age groups.

Source Monitoring Task

A mixed between-within subjects ANOVA was performed to assess the impact of age group and auditory stimuli on the source memory scores. The analysis revealed no main effect of auditory stimuli, $F(1,58) = .383, p = .538, \eta^2 = .007$, no main effect of age group, $F(1,58) = 6.143, p = .016, \eta^2 = .096$, and no interaction effect between age group and auditory stimuli, $F(1,58) = 1.521, p = .222, \eta^2 = .026$ (see Table 3).

Very few children correctly refuted the false alarms from the recognition task during the source monitoring task. In order to compare the scores for the correctly rejected false alarms for the two age groups, an independent-samples t-test was performed. Five children did not perform the source monitoring task for the false alarms. There was no significant difference in scores between the two age groups, $t(53) = -.569, p = .572$, two-tailed.

Individual Differences

The relationships between IQ scores and recall, recall in order, d' and source memory scores were investigated using Pearson product-moment correlation coefficients. Three children did not perform the WASI, and were excluded from the analysis. There were significant positive correlations between Full Scale IQ and recall scores, $r = .292, n = 57, p = .028$, two-tailed, and Full Scale IQ and recall in order scores, $r = .310, n = 57, p = .019$, two-tailed. A higher Full Scale IQ score was associated with greater performance on the cued recall task. According to the explained variance r^2 , Full Scale IQ scores helped explain 8.5 % of the variance in recall scores and 9.6 % of the variance in recall in order scores.

Discussion

Results from the present study support the first hypothesis stating that the children would remember the emotional sound event better than the neutral sound event. Emotional stimuli were remembered significantly better than neutral stimuli during the recall and recognition tasks. The second main hypothesis, postulating that older children would outperform younger children during the recall, recognition and source monitoring tasks, was partially supported. Older children performed the recall task significantly better than the younger age group, but for d' and source monitoring scores, no significant effect of age group appeared. Lastly, we hypothesized that there would be a positive correlation between intelligence scores from the WASI and the different memory scores. Significant, positive correlations were confirmed between Full Scale IQ and performance in the cued recall task.

Emotional Sound Events Impact Memory

Results from the present study are in compliance with the robust finding that emotional material is remembered better than neutral material (Bradley et al., 1992; Bywaters et al., 2004; Mirandola et al., in press). These results have been confirmed both inside and outside of the laboratory setting (Kensinger & Schacter, 2006; Peterson & Whalen, 2001; Putman et al., 2004). In accordance with the present results, Bradley and Lang (2000) reported that emotionally arousing individual environmental sounds were recalled significantly better than neutral sounds. To our knowledge, no previous studies have investigated the effect of emotionality on memory for environmental sound events. The present findings that emotional sound events are remembered more accurately than neutral sound events confirm and expand the previously reported superiority of emotional material.

Practical implications of the reported emotional memory advantage in a forensic context may be derived. The improved accuracy and robustness of memories for emotional material compared to memories for neutral material is advantageous because of the emotionally charged nature of most to-be-remembered material in a legal context. Negatively charged emotional events are the basis for criminal allegations, and the memory superiority of emotional material is thus beneficial. Indeed, discerning that emotionally charged environmental sound events are remembered better than neutral environmental sound events has practical importance in the legal arena, as well as theoretical significance.

The reported difference between emotional and neutral material in the cued recall and recognition tasks can be the result of several factors. Encoding of the emotional sound event and the neutral sound event was potentially accompanied by somewhat different cognitive processes (Phelps, 2006). While listening to the car crash event, the secondary auditory cortex compared the incoming stimuli with stored knowledge of the same emotional valence. This comparison probably resulted in an emotional reaction in the children (Purves et al., 2008). The emotional reaction could further lead to increased and narrowed attention during encoding of the emotional sound event. Increased attention effectively enhanced encoding, improving memorability of the emotional sound event compared to the neutral sound event (Hamann, 2001). In addition, differences during consolidation of the emotional and neutral sound events could have been present during the two week delay between encoding and memory testing. The memory for the car crash event professedly underwent slightly different consolidation processes during delay than the tooth brushing event. This enhanced consolidation could lead to improved storage of the car crash event (Kleinsmith & Kaplan, 1963). Even though the same experimental conditions were present during encoding and delay of both sound events, different cognitive processes during encoding and consolidation could be present.

Increased rehearsal and repetition of the emotional sound event compared to the neutral sound event could furthermore be the cause of the memory superiority of the car crash event (Breslin & Safer, 2011; Brown & Kulik, 1977). The children perhaps overtly and covertly repeated and rehearsed the car crash event the most by telling family and friends about the event, as well as thinking about the sound event themselves. This increased rumination could effectively improve memorability of the emotional sound event. Differences in repetition and rehearsal during the two week delay were impossible to experimentally control. The present study cannot conclude whether enhanced encoding, consolidation or rehearsal was the reason for the observed emotional memory superiority. Several factors most likely contributed to children recalling and recognizing the emotional sound event significantly better than the neutral sound event. The interplay of these factors can in combination lead the children to remember the car crash event better than the tooth brushing event.

Laboratory studies in witness psychology have been criticized for having low external validity and ability to generalize to real criminal incidents. Emotional arousal induced by arousing sounds, pictures, words or videos are probably less emotionally activating than

witnessing or experiencing a genuine criminal event (Eysenck, 2009a). Laboratory studies cannot expose participants to extreme levels of stress and trauma, and can lack the ability to mimic such traumatic events as sexual abuse or kidnapping. Ethical guidelines confine the level of emotionality that can be induced in participants in laboratory studies. Another potential aspect limiting the generalizability of laboratory studies, such as the present one, is that these studies are not as personally involving as real life criminal incidents. When children listened to the environmental sound events in the present study, they were passive bystanders instead of interacting participants in an event. Whether witnesses are active participants or passive bystanders can potentially influence memory (Tobey & Goodman, 1992). The context of the study can also influence the perception of sounds. Some sounds are most likely perceived differently in a laboratory setting than in a real setting (Gygi & Shafiro, 2007). For instance, the sound of a lion roaring will be perceived and experienced very differently in a laboratory and a jungle, and the sound of gun shots in a dark alley is guaranteed to be more frightening than hearing gun shots through headphones.

Despite that questions have been raised concerning the ecological validity of laboratory studies, field studies generally report similar results and tendencies as laboratory studies (Baugerud & Melinder, 2012; Peterson & Whalen, 2001). In a similar vein as the current laboratory results, Peterson & Whalen (2001) concluded that children between the ages of 2 to 13 years remembered a real emotionally arousing event better than a less arousing event. Field studies reporting increased memory for central compared to peripheral information during emotionally arousing events are also in compliance with laboratory studies (Baugerud & Melinder, 2012). Since few published studies have explored children's ability to remember auditive stimuli, a laboratory study is a good starting point to elucidate the different variables potentially influencing memorability. Experimental studies in a laboratory setting are furthermore a necessity in order to be able to study phenomena that cannot be manipulated in real life, such as abuse, kidnap or other damaging events. Studies utilizing real world criminal events or naturally occurring disasters or injuries as opposed to experimental paradigms are quasi-experimental and retrospective in nature. Experimental studies are advantageous and sound methods to utilize in a witness psychology context, and we think that our results may offer insight into real life witness testimonies.

The Varying Effect of Age

Clear age differences between the older and younger children were evident in the cued recall task. Approximately one third of the children aged 7-8 years were in fact unable to recall any of the sounds they had listened to in the Eksploratorium. The present results indicating a memory superiority for the older children in the recall task was in accordance with current literature (Qin et al., 2002; Reese, 2009). A significant effect of age group in recall in order scores can indicate that younger children have greater difficulty recalling items in the order of presentation. Since young children have problems remembering how an event occurred (Melinder et al., 2010) and the chronological order of an autobiographical event (Reese, 2009), a significant age difference between children aged 7-8 years and 9-11 years for recall in order scores was expected. Younger children have greater difficulty not only recalling information, but recalling the items in the correct order of presentation. This can be especially debilitating in a witness context, where the order of events and the narrative feel of a testimony is of extra importance. The present results confirm and expand the notion that older children outperform younger children despite modality.

Even though we can state that older children performed the cued recall task better than younger children, the present study was unable to establish the factors responsible for this age difference. Younger children may perform poorer than older children because of a number of factors. The younger children could for instance have greater difficulty perceiving, interpreting and understanding the sound events during encoding. Since younger children have fewer previous experiences and stored knowledge to compare incoming stimuli with (Eysenck, 2009b), the sound events may not be perceived, recognized, and understood as efficiently and correctly as in older children. This was especially evident when some of the younger children narrated the environmental sound events wrongly during encoding, stating that the sounds were something other than intended. Moreover, younger children professedly have greater difficulty understanding the memory tasks and concentrating during both encoding and retrieval. Several of the younger children potentially found the tasks difficult to comprehend and perform, and their concentration was visibly poorer than in the oldest age group.

If an age difference in memory was the reason for the differing performance in the present task, the current study cannot with certainty conclude whether the difference was a result of varying abilities during encoding, storage, consolidation, or retrieval of long-term

memories, or whether the increase in performance resulted from improved content knowledge, working memory, metamemory, or memory strategies (Siegler, 1991). Seeing as younger children possess less stored content knowledge and previous experiences to compare the sound events to than older children, their memory performance would suffer as a consequence (Eysenck, 2009b). Increased content knowledge improves memory, rendering older children more capable of remembering the sound events. Because the prefrontal cortex develops with age, the youngest age group probably also possessed fewer memory strategies and metamemory, making them less competent at effectively encoding and remembering information (Gathercole, 1998). The youngest children's lesser developed working memory capacities probably also contributed to the difference in performance (Siegler, 1991). Most likely, older children remembered more environmental sounds than younger children because of several connected reasons that simultaneously influenced performance. The improved performance accompanying increased age is likely a result of the older children's progressed perception, understanding, concentration, and memory.

Children in both age groups performed the recognition task fairly well, as evident by a high d' in both groups. Thus, the second hypothesis was not confirmed in the recognition task. Children's generally high performance most likely indicated that the task was relatively undemanding and straightforward. The distracter sounds in the current task deviated from the target sounds in both auditive composition and semantic meaning. A greater number of distracter sounds, or distracter sounds more closely resembling target sounds in semantic meaning or auditive composition would perhaps make the recognition task more difficult. By making the recognition task more difficult, age differences would probably increase.

The current results supported the assumption that age differences would be larger in the recall task than the recognition task, and coincides with previous results reporting the same relation (Hudson & Fivush, 1991; List, 1986). Without further cues or assistance, the youngest children aged 7-8 years were moderately proficient at recalling the environmental sounds, while the oldest children aged 9-11 years performed reasonably well. Younger children obviously have more to gain by memory cuing compared to older children. This marked difference in variability dependent on task is probably a result of the finding that the memory of younger children is more reliant on cues and probing (Hudson & Fivush, 1991). Younger children have disproportionately greater difficulty recalling compared to recognizing information, and their memory performance will consequently improve more following probing than older children's performance.

Present source memory scores failed to yield a significant main effect of age between the two age groups. This lacking effect was potentially a result of the evident ceiling effect in the source monitoring task. When disregarding emotional valence, the mean percentage of correctly appointed sounds was 83.4 % for the youngest children and 92.9 % for the oldest children. In fact, over half of the children in the study were able to appoint the correct source to all the environmental sounds. The apparent ceiling effect is probably a result of the inherent characteristics of the source monitoring task. Even if the children did not remember the environmental sounds from encoding, they could to a large degree figure out the probable source of the hits based on characteristics of the sound. The sound in itself gave a clear indication of the probable source.

Another possible explanation was that the lacking effect of age reflected true similar abilities between the youngest and oldest children. Children ranging in age from 7 to 11 years can in fact have the same inherent abilities required to solve the memory source monitoring task if the sources are relatively dissimilar. The two sources in the present study were arguably dissimilar, especially because the sounds themselves indicated the likely source. Previous studies have reported that children of different ages perform on a similar level on some memory source monitoring tasks (Ackil & Zaragoza, 1995; Lindsay et al., 1991), even though the majority of studies report increasing memory performance with increasing age (Melinder et al., 2006; Ruffman et al., 2001).

Limited research has investigated the relationship between age and memory for auditive stimuli, and the exact connection between age and earwitness performance is still unknown (Ling & Coombe, 2005). As a step in the right direction, the current study helped clarify this relationship, and indicated that age differences in memory for environmental sound events mimics literature regarding memory for other modalities. The current study expands the literature stating that older children are in general more accurate witnesses than younger children.

Memory Performance and Intelligence

The correlation analysis indicated that children with a high score on the Full Scale IQ scale performed the cued recall task better. These correlations were significant, but according to the explained variance, the IQ scores helped explain only 8-10 % of the variance in

performance. Previous literature has both confirmed and refuted a positive relationship between intelligence and memory performance (Greenhoot et al., 1999; Gross & Hayne, 1999; Melinder et al., 2010). Particularly, a correlation between verbal intelligence and performance in interviews has been previously reported (Melinder et al., 2010). In a similar vein, the present study reported a correlation between intelligence and performance in the cued recall task. Children with high IQ evidently performed the cued recall task better than less developed children. This relationship is probably somewhat a result of the verbal skills needed to perform such tasks (Qin et al., 2002).

The influence of other individual factors in addition to intelligence might potentially be the cause of the relatively small explained variance of 8-10 % in the present study. Intelligence is postulated to have an impact on memory performance, and arguments can be made for the importance of other individual factors as well. Executive functions have for instance been found to positively correlate with children's performance in a recognition task and be associated with better resistance to suggestible questioning (Melinder et al., 2006). Most likely, several individual factors are in combination the cause of the varying memory performance observed within the same age group.

Children's Earwitness Testimonies

The combined body of results from the present study indicated that children are in general moderately accurate earwitnesses. Children aged 9-11 years displayed a combined accurate recall of 33 %, while children aged 7-8 years accurately recalled approximately 15 % of the environmental sounds. The oldest children were fairly proficient witnesses, while the younger children performed moderately well in the cued recall task. These results clearly indicate that memory for auditive stimuli was well below the generally very accurate memory for pictures (Cohen et al., 2009). Children also performed below the average percentage of approximately 50 % displayed when adults recall environmental sounds (Bartlett, 1977; Crutcher & Beer, 2011; Ferrara et al., 1978; Huss & Weaver, 1996; Paivio et al., 1975; Philipchalk & Rowe, 1971; Thompson & Paivio, 1994). Most of these previous studies however employed a very short delay in comparison to the present study. The majority of the previous literature also utilized individual environmental sounds, potentially leading to a different memory performance than when using environmental sound events.

During the recognition task, all the children performed above chance with d' scores between 1 and 2. The children displayed a relatively high sensitivity and were generally proficient at recognizing previously presented sounds. Children in both age groups also performed well in the source monitoring task. All the children were able to accurately relate approximately 80 – 90 % of the environmental sounds to the correct source. Clearly, children are moderately reliable earwitnesses, who are able to recall and recognize environmental sound events and appoint sounds to the correct source with a reasonable accuracy. Especially the oldest children aged 9-11 years displayed rather proficient memory abilities.

Limitations of the Present Study

One caveat with the present study was that only two sound events, one emotional and one neutral, were utilized. When utilizing only one emotional and one neutral sound event, the internal validity of the study can be weakened because the reported difference in emotionality can potentially be the result of other differences between the two sound events. Several measures were taken to secure the similarity between the two sound events when it came to length, volume, familiarity, number of sounds, and length of individual sounds. Utilization of two sound events was justified in this study. The entire project conducted in the Eksploratorium was time-consuming and tiresome for the youngest participants, necessitating the use of only two sound events. If more sound events had been utilized, the duration of the recognition task would increase.

Since the cued recall, recognition, and source memory tasks were performed after an interview, the children could be fatigued and respond poorer than if they did not undergo an interview beforehand. Long and tiresome interrogations are the reality in real life criminal investigations and the generally one hour long interaction with the participants in the present study is probably shorter than the interrogation in many criminal cases. Another factor that could potentially decrease performance is the fact that children were bombarded with stimuli in the Eksploratorium, hence confusing memory of the environmental sound events. The other confusing elements can potentially lower performance in comparison to encoding with the sound events alone. Arguments can be postulated that this confusion of information to the senses is a common aspect of criminal incidents. Auditive information is often a part of a complex sensory environment. The external validity of the present study was therefore arguably enhanced by the preceding interview and the confusing elements during encoding.

On the other hand, children's performance could potentially be elevated following rehearsal and repetition both internally and through conversations with family and friends. Even though parents were discouraged to question their children about the Eksploratorium, the children could naturally explain as much as they liked. Rehearsal and repetition is also a natural part of criminal investigations. Witnesses often repeat their testimonies, both overtly and covertly. The children's performance could also potentially be elevated because of the high socio-economic status of most of our participants. Despite contacting all primary schools in the Oslo region, the majority of participants came from areas with high socio-economic status and abundant resources. This is a common problem when relying on volunteerism.

Another potential limitation of the present study was that the emotional nature of the two sound events was only assumed without actually testing that the emotional sound event was perceived as emotional, and the neutral sound event as neutral. In reality, the children could have perceived the sound events differently. The emotional nature of the sound events could have been tested by using either physiological measures such as heart rate during encoding, or by self report following encoding. This would instantly increase the resources and time needed to conduct the study.

Future Directions

Future studies should aim to further elucidate the potential influence of different factors on the reliability of children's earwitness testimonies. Limited research regarding children's performance as earwitnesses warrants further investigation into this socially important topic. In addition to cross-sectional studies like the present study, longitudinal studies should be used in order to further specify the relationship between age and earwitness performance. Longitudinal studies have advantages over cross-sectional studies and are optimal for investigating cognitive development with age.

Future research would benefit from scoring commission errors as well as errors of omission during the recall task. An equally debilitating problem as forgetting details and information in witness testimonies is when witnesses produce false memories and recall information that was in fact not present during encoding. Such errors of commission were evident in the present cued recall task, but they were not systematically scored. Younger children can potentially have a higher likelihood of making such commission errors.

Studies can further expand the current results by incorporating more environmental sound events, as well as positive sound events. Since child abuse often involves even younger children than the participants in this study, future research can additionally aim towards clarifying how well younger children remember environmental sound events. Other groups of participants can also be used in future studies. It would be especially interesting to investigate potential differences between typically developed children and children exposed to abuse or neglect, given that the latter group is more often a witness in real life criminal cases.

The last frontier for all practically aimed research is to replicate laboratory studies in naturalistic environments. A future aim for research investigating children's earwitness performance is to incorporate naturalistic environments and simulate an earwitness situation comparable to real life criminal incidents. The use of naturalistic settings increases external validity and generalizability, making us further capable of informing relevant officials.

Concluding Remarks

The aim of the present study was to further understand children's earwitness testimonies. The impact of age, individual differences and the emotionality of the auditive stimuli on performance in a cued recall, recognition and source monitoring task was studied. The results indicated that the emotional sound event was recalled and recognized more accurately than the neutral sound event. In addition, the results revealed that older children aged 9-11 years performed better than younger children aged 7-8 years in the cued recall task. The performance of the children in the cued recall task correlated with Full Scale IQ, measured with the WASI.

Information concerning the witness testimonies of children and the reliability of their memory is crucial in order to be able to ensure justice for child victims of crime. As a weak party in legal disputes and an easy target for reliability accusations, the rights of child witnesses must be constantly advocated. Further knowledge concerning children's earwitness testimonies is hence vital for this mission to succeed, especially considering the limited previous literature concerning earwitnesses. As a contribution to the debate regarding children's reliability as witnesses, as well as a step in the right direction in order to strengthen children's position within the judicial system, the present study indicated that children are fairly accurate earwitnesses.

References

- Ackil, J. K., & Zaragoza, M. S. (1995). Developmental Differences in Eyewitness Suggestibility and Memory for Source. *Journal of Experimental Child Psychology*, 60(1), 57-83.
- Bartlett, J. C. (1977). Remembering environmental sounds: The role of verbalization at input. *Memory & Cognition*, 5(4), 404-414.
- Bartol, C. R., & Bartol, A. M. (2012). *Introduction to Forensic Psychology: Research and Application* (3 ed.). Thousand Oaks, CA: Sage Publications.
- Baugerud, G. A., & Melinder, A. (2012). Maltreated Children's Memory of Stressful Removals from Their Biological Parents. *Applied Cognitive Psychology*, 26(2), 261-270.
- Bayer, M., Sommer, W., & Schacht, A. (2011). Emotional words impact the mind but not the body: Evidence from pupillary responses. *Psychophysiology*, 48(11), 1553-1561.
- Bernstein, D. A., Penner, L. A., Clarke-Stewart, A., & Roy, E. J. (2006). *Psychology* (7 ed.). Boston, NY: Houghton Mifflin Company.
- Bradley, M. M., Greenwald, M. K., Petry, M. C., & Lang, P. J. (1992). Remembering pictures: Pleasure and arousal in memory. *Journal of Experimental Psychology-Learning Memory and Cognition*, 18(2), 379-390.
- Bradley, M. M., & Lang, P. J. (2000). Affective reactions to acoustic stimuli. *Psychophysiology*, 37(2), 204-215.
- Breslin, C. W., & Safer, M. A. (2011). Effects of Event Valence on Long-Term Memory for Two Baseball Championship Games. *Psychological Science*, 22(11), 1408-1412.
- Brown, R., & Kulik, J. (1977). Flashbulb Memories. *Cognition*, 5(1), 73-99.

- Bruck, M., Ceci, S. J., & Hembrooke, H. (1998). Reliability and credibility of young children's reports: From research to policy and practice. *American Psychologist*, 53(2), 136-151.
- Bywaters, M., Andrade, J., & Turpin, G. (2004). Determinants of the vividness of visual imagery: The effects of delayed recall, stimulus affect and individual differences. *Memory*, 12(4), 479-488.
- Ceci, S. J., & Bruck, M. (1993). Suggestibility of the child witness: A historical review and synthesis. *Psychological Bulletin*, 113(3), 403-439.
- Ceci, S. J., & Bruck, M. (1995). *Jeopardy in the Courtroom: A Scientific Analysis of Children's Testimony*. Washington, DC: American Psychological Association.
- Ceci, S. J., Loftus, E. F., Leichtman, M. D., & Bruck, M. (1994). The Possible Role of Source Misattributions in the Creation of False Beliefs Among Preschoolers. *International Journal of Clinical and Experimental Hypnosis*, 42(4), 304-320.
- Christianson, S. A. (1992). Emotional stress and eyewitness memory: A critical review. *Psychological Bulletin*, 112(2), 284-309.
- Clapp, W. C., Kirk, I. J., Hamm, J. P., Shepherd, D., & Teyler, T. J. (2005). Induction of LTP in the human auditory cortex by sensory stimulation. *European Journal of Neuroscience*, 22(5), 1135-1140.
- Clark, M., Stamm, S., Sussman, R., & Weitz, S. (1974). Encoding of auditory stimuli in recognition memory tasks. *Bulletin of the Psychonomic Society*, 3, 177 - 178.
- Cohen, M. A., Horowitz, T. S., & Wolfe, J. M. (2009). Auditory recognition memory is inferior to visual recognition memory. *Proceedings of the National Academy of Sciences of the United States of America*, 106(14), 6008-6010.
- Crutcher, R. J., & Beer, J. M. (2011). An auditory analog of the picture superiority effect. *Memory & Cognition*, 39(1), 63-74.

- Cycowicz, Y. M., & Friedman, D. (1999). The effect of intention to learn novel, environmental sounds on the novelty P3 and old new recognition memory. *Biological Psychology*, 50(1), 35-60.
- Et ansvarlig politi: Åpenhet, kontroll og læring [A responsible police: Openness, control and learning]* (2009). Justis- og politidepartementet: Norges offentlige utredninger.
- Eysenck, M. W. (2009a). Eyewitness testimony. In A. Baddeley, M. W. Eysenck, & M. C. Anderson (Eds.), *Memory* (pp. 317-342). Hove, England: Psychology Press.
- Eysenck, M. W. (2009b). Memory in childhood. In A. Baddeley, M. W. Eysenck, & M. C. Anderson (Eds.), *Memory* (pp. 267-291). Hove, England: Psychology Press.
- Ferrara, R. A., Puff, C. R., Gioia, G. A., & Richards, J. M. (1978). Effects of incidental and intentional learning instructions on the free recall of naturalistic sounds. *Bulletin of the Psychonomic Society*, 11(6), 353 - 355.
- Fivush, R. (2002). Event memory in early childhood. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 139-161). Hove, England: Psychology Press.
- Foley, M. A., & Johnson, M. K. (1985). Confusions between memories for performed and imagined actions: A developmental comparison. *Child Development*, 56(5), 1145-1155.
- Foley, M. A., Johnson, M. K., & Raye, C. L. (1983). Age-related changes in confusion between memories for thoughts and memories for speech. *Child Development*, 54(1), 51-60.
- Foley, M. A., Santini, C., & Sopasakis, M. (1989). Discriminating Between Memories - Evidence for Children's Spontaneous Elaborations. *Journal of Experimental Child Psychology*, 48(1), 146-169.
- Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 39(1), 3-27.

- Goodman, G. S., & Melinder, A. (2007). Child witness research and forensic interviews of young children: A review. *Legal and Criminological Psychology*, 12, 1-19.
- Greenhoot, A. F., Ornstein, P. A., Gordon, B. N., & Baker-Ward, L. (1999). Acting out the details of a pediatric check-up: The impact of interview condition and behavioral style on children's memory reports. *Child Development*, 70(2), 363-380.
- Gross, J., & Hayne, H. (1999). Drawing facilitates children's verbal reports after long delays. *Journal of Experimental Psychology-Applied*, 5(3), 265-283.
- Gygi, B., & Shafiro, V. (2007). General functions and specific applications of environmental sound research. *Frontiers in Bioscience*, 12, 3152-3166.
- Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, 5(9), 394-400.
- Hanten, G., Li, X. Q., Chapman, S. B., Swank, P., Gamino, J., Roberson, G., & Levin, H. S. (2007). Development of verbal selective learning. *Developmental Neuropsychology*, 32(1), 585-596.
- Harand, C., Bertran, F., La Joie, R., Landeau, B., Mezenge, F., Desgranges, B., . . . Rauchs, G. (2012). The Hippocampus Remains Activated over the Long Term for the Retrieval of Truly Episodic Memories. *Plos One*, 7(8), 1-14.
- Holliday, R. E. (2003). Reducing misinformation effects in children with cognitive interviews: Dissociating recollection and familiarity. *Child Development*, 74(3), 728-751.
- Hollien, H. F. (1990). *The acoustics of crime: The new science of forensic phonetics*. New York, NY: Plenum Press.
- Howe, M. L. (2006). Developmentally invariant dissociations in children's true and false memories: Not all relatedness is created equal. *Child Development*, 77(4), 1112-1123.

- Hudson, J. A., & Fivush, R. (1991). As Time Goes By: Sixth Graders Remember a Kindergarten Experience. *Applied Cognitive Psychology*, 5(4), 347-360.
- Huss, M. T., & Weaver, K. A. (1996). Effect of modality in earwitness identification: Memory for verbal and nonverbal auditory stimuli presented in two contexts. *Journal of General Psychology*, 123(4), 277-287.
- Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, 114(1), 3-28.
- Kensinger, E. A., & Schacter, D. L. (2006). Amygdala activity is associated with the successful encoding of item, but not source, information for positive and negative stimuli. *Journal of Neuroscience*, 26(9), 2564-2570.
- Kleinsmith, L. J., & Kaplan, S. (1963). Paired-associate learning as a function of arousal and interpolated interval. *Journal of Experimental Psychology*, 65(2), 190-193.
- Kraus, N., & Banai, K. (2007). Auditory-processing malleability: Focus on language and music. *Current Directions in Psychological Science*, 16(2), 105-110.
- Lamb, M. E., Sternberg, K. J., & Esplin, P. W. (2000). Effects of age and delay on the amount of information provided by alleged sex abuse victims in investigative interviews. *Child Development*, 71(6), 1586-1596.
- Lawrence, D. M., & Banks, W. P. (1973). Accuracy of recognition memory for common sounds. *Bulletin of the Psychonomic Society*, 1(5A), 298-300.
- Lawrence, D. M., Cobb, N. J., & Beard, J. I. (1979). Comparison of accuracy in auditory and tactile recognition memory for environmental stimuli. *Perceptual and Motor Skills*, 48(1), 63-66.
- Lindsay, D. S., Johnson, M. K., & Kwon, P. (1991). Developmental changes in memory source monitoring. *Journal of Experimental Child Psychology*, 52(3), 297-318.

- Ling, J., & Coombe, A. (2005). Age effects in earwitness recall of a novel conversation. *Perceptual and Motor Skills*, 100(3), 774-776.
- List, J. A. (1986). Age and Schematic Differences in the Reliability of Eyewitness Testimony. *Developmental Psychology*, 22(1), 50-57.
- Magnussen, S. (2007). *Vitnepsykologi: Pålitelighet og troverdighet i dagligliv og rettssal* [Witness psychology: Reliability and credibility in everyday life and courtroom]. Oslo, Norway: Abstrakt forlag as.
- Marcell, M., Malatanos, M., Leahy, C., & Comeaux, C. (2007). Identifying, rating, and remembering environmental sound events. *Behavior Research Methods*, 39(3), 561-569.
- McAdams, S., & Bigand, E. (1993). Introduction to auditory cognition. In S. McAdams, & E. Bigand (Eds.), *Thinking in sound: The cognitive psychology of human audition* (pp. 1-8). Oxford, England: Oxford University Press.
- Melinder, A., Alexander, K., Cho, Y. I., Goodman, G. S., Thoresen, C., Lonnum, K., & Magnussen, S. (2010). Children's eyewitness memory: A comparison of two interviewing strategies as realized by forensic professionals. *Journal of Experimental Child Psychology*, 105(3), 156-177.
- Melinder, A., Endestad, T., & Magnussen, S. (2006). Relations between episodic memory, suggestibility, theory of mind, and cognitive inhibition in the preschool child. *Scandinavian Journal of Psychology*, 47(6), 485-495.
- Memon, A., & Yarmey, A. D. (1999). Earwitness recall and identification: Comparison of the cognitive interview and the structured interview. *Perceptual and Motor Skills*, 88(3), 797-807.
- Miller, J. D., & Tanis, D. C. (1971). Recognition memory for common sounds. *Psychonomic Science*, 23(4), 307-308.

- Mirandola, C., Toffalini, E., Grassano, M., Cornoldi, C., & Melinder, A. (in press). Inferential false memories of events: Negative consequences protect from distortions when the events are free from further elaboration. *Memory*, 1-11.
- Music Technology Group of Universitat Pompeu Fabra (2012). [Online Database]. Retrieved from freesound.org.
- Näätänen, R., & Winkler, I. (1999). The concept of auditory stimulus representation in cognitive neuroscience. *Psychological Bulletin*, 125(6), 826-859.
- Opitz, B., Mecklinger, A., & Friederici, A. D. (2000). Functional asymmetry of human prefrontal cortex: Encoding and retrieval of verbally and nonverbally coded information. *Learning & Memory*, 7(2), 85-96.
- Paivio, A., Philipchalk, R., & Rowe, E. J. (1975). Free and serial recall of pictures, sounds, and words. *Memory & Cognition*, 3(6), 586-590.
- Parkin, A. J. (2002). The development of procedural and declarative memory. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 113-137). Hove, England: Psychology Press.
- Peterson, C., & Whalen, N. (2001). Five years later: Children's memory for medical emergencies. *Applied Cognitive Psychology*, 15(7), 7-24.
- Phelps, E. A. (2006). Emotion and cognition: Insights from studies of the human amygdala. *Annual Review of Psychology*, 57, 27-53.
- Philipchalk, R. P., & Rowe, E. J. (1971). Sequential and nonsequential memory for verbal and nonverbal auditory stimuli. *Journal of Experimental Psychology*, 91(2), 341-343.
- Pinel, J. P. J. (2000). *Biopsychology*. Needham Heights, MA: Allyn & Bacon.
- Purves, D., Brannon, E. M., Cabeza, R., Huettel, S. A., LaBar, K. S., Platt, M. L., & Woldorff, M. G. (2008). *Principles of Cognitive Neuroscience*. Sunderland, MA: Sinauer Associates.

- Putman, P., van Honk, J., Kessels, R. P. C., Mulder, M., & Koppeschaar, H. P. F. (2004). Salivary cortisol and short and long-term memory for emotional faces in healthy young women. *Psychoneuroendocrinology*, 29(7), 953-960.
- Qin, J., Quas, J. A., Redlich, A. D., & Goodman, G. S. (2002). Children's eyewitness testimony: Memory development in the legal context. In N. Cowan (Ed.), *The development of memory in childhood* (pp. 301-341). Hove, England: Psychology Press.
- Quas, J. A., Malloy, L. C., Melinder, A., Goodman, G. S., D'Mello, M., & Schaaf, J. (2007). Developmental differences in the effects of repeated interviews and interviewer bias on young children's event memory and false reports. *Developmental Psychology*, 43(4), 823-837.
- Reese, E. (2009). The development of autobiographical memory: Origins and consequences. In P. Bauer (Ed.), *Advances in Child Development and Behavior* (pp. 145-200). San Diego, CA: Elsevier Academic Press Inc.
- Ruffman, T., Rustin, C., Garnham, W., & Parkin, A. J. (2001). Source monitoring and false memories in children: Relation to certainty and executive functioning. *Journal of Experimental Child Psychology*, 80(2), 95-111.
- Röder, B., & Rösler, F. (2003). Memory for environmental sounds in sighted, congenitally blind and late blind adults: Evidence for cross-modal compensation. *International Journal of Psychophysiology*, 50, 27-39.
- Schmolck, H., Buffalo, E. A., & Squire, L. R. (2000). Memory distortions develop over time: Recollections of the O.J. Simpson trial verdict after 15 and 32 months. *Psychological Science*, 11(1), 39-45.

- Schulze, K., Vargha-Khadem, F., & Mishkin, M. (2012). Test of a motor theory of long-term auditory memory. *Proceedings of the National Academy of Sciences of the United States of America*, 109(18), 7121-7125.
- Siegler, R. S. (1991). *Children's thinking*. Upper Saddle River, NJ: Prentice Hall.
- Snyder, J. S., & Gregg, M. K. (2011). Memory for sound, with an ear toward hearing in complex auditory scenes. *Attention, Perception & Psychophysics*, 73(7), 1993-2007.
- Thompson, V. A., & Paivio, A. (1994). Memory for pictures and sounds: Independence of auditory and visual codes. *Canadian Journal of Experimental Psychology*, 48(3), 380-398.
- Tobey, A. E., & Goodman, G. S. (1992). Children's Eyewitness Memory: Effects of Participation and Forensic Context. *Child Abuse & Neglect*, 16(6), 779-796.
- Tulving, E. (1972). Episodic and Semantic Memory. In E. Tulving, & W. Donaldson (Eds.), *Organization of Memory* (pp. 381-402). New York, NY: Academic Press.
- Wechsler, D. (1989). *Wechsler Preschool and Primary Scale of Intelligence – Revised*. San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (1999). *Wechsler Abbreviated Scale of Intelligence (WASI)*. San Antonio, TX: Harcourt Assessment.
- Wessinger, C. M., VanMeter, J., Tian, B., Van Lare, J., Pekar, J., & Rauschecker, J. P. (2001). Hierarchical organization of the human auditory cortex revealed by functional magnetic resonance imaging. *Journal of Cognitive Neuroscience*, 13(1), 1-7.
- Yarmey, A. D., Yarmey, M. J., & Todd, L. (2008). Frances McGehee (1912-2004): The first eyewitness researcher. *Perceptual and Motor Skills*, 106(2), 387-394.
- Zucco, G. M. (2003). Anomalies in cognition: Olfactory memory. *European Psychologist*, 8(2), 77-86.

